PUBLICATION 853 ISSUED DECEMBER, 1950

PROPERTY OF MAIN LIBRARY, DEPARTMENT
OF AGRICULTURE, OTTAWA
Lent to...
Date...
PLEASE RETURN
AL 32 9207—1PM—446

ORGANIC SOIL MANAGEMENT FOR VEGETABLES

By

F. S. BROWNE
Division of Horticulture

DOMINION EXPERIMENTAL SUBSTATION
FOR MUCKLANDS, STE-CLOTHILDE, QUEBEC

EXPERIMENTAL FARMS SERVICE

DEPARTMENT OF AGRICULTURE
OTTAWA, CANADA

630.4
C212
P 853
1950
OOAg
c.3

51—PM—1050

Digitized by the Internet Archive
in 2012 with funding from
Agriculture and Agri-Food Canada – Agriculture et Agroalimentaire Canada

http://www.archive.org/details/organicsoilmanag00brow

CONTENTS

PAGE

INTRODUCTION.......... 3

ORIGIN AND CLASSIFICATION.......... 5
- Soil Reaction.......... 6

FERTILIZER REQUIREMENTS OF ORGANIC SOILS.......... 8
- Potash.......... 8
- Phosphorus.......... 11
- Nitrogen.......... 12
- Method of Applying Commercial Fertilizers.......... 14
- Use of Barnyard Manure.......... 16

MINOR ELEMENT REQUIREMENTS OF ORGANIC SOILS.......... 17
- Copper.......... 17
- Boron.......... 18
- Manganese.......... 19
- Sulphur.......... 20
- Common Salt.......... 20
- Zinc.......... 20

WATER CONTROL.......... 20

SOIL MANAGEMENT.......... 27
- Seeding.......... 30
- Cultivation.......... 30
- Protection From Wind.......... 30
- Frost Prevalence.......... 32
- Crop Sequence.......... 33
- Weed Control.......... 33

SUMMARY OF FERTILIZER RECOMMENDATIONS.......... 35

ORGANIC SOIL MANAGEMENT FOR VEGETABLES IN QUEBEC AND EASTERN ONTARIO

Introduction

This bulletin has been prepared with the object of providing information to those interested in the production of vegetable crops on organic soils in Quebec and Eastern Ontario. Much of the data used has been obtained from the results of experiments conducted at the Dominion Experimental Substation for mucklands at Ste. Clothilde, Quebec, which was established in 1936.

Additional information was also obtained from experiments and observations on other muckland areas in Ontario and Quebec.

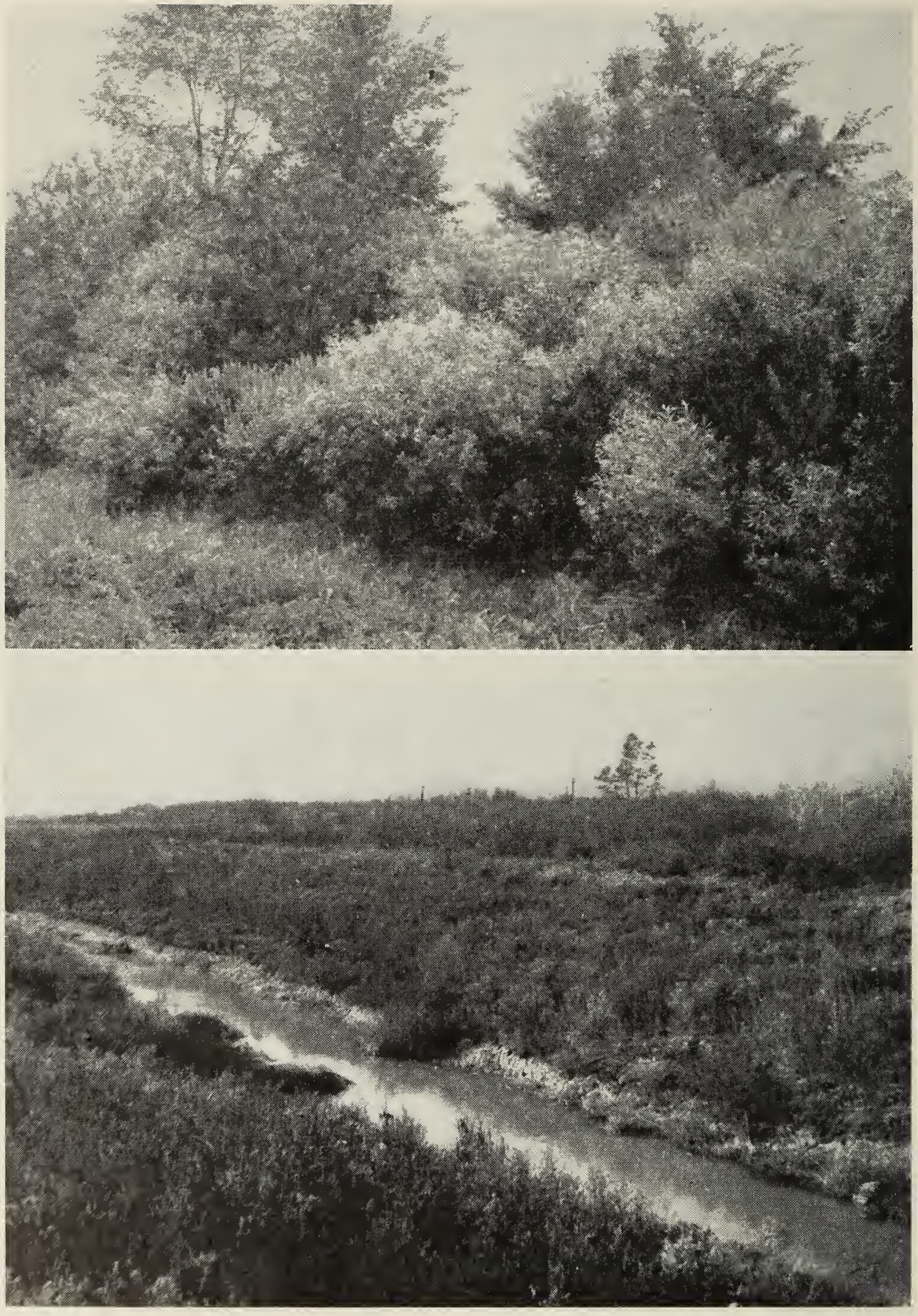
In Ontario a Substation operated by the Ontario Provincial Government is located at Bradford, on the Holland marsh. At this Substation investigations are being conducted relative to the particular organic soil conditions and the climate of that region.

On the organic soils of Eastern Canada there are excellent opportunities for extensive production of vegetable crops. A complete survey of these areas has not been made but there are at least 250,000 acres that could be developed profitably. In the muckland areas of eastern Ontario and Quebec less than 20,000 acres are utilized for the production of vegetable crops and a much smaller area is used for this purpose in the Maritime Provinces. In southwestern Quebec the organic soils have been surveyed and classified by the Quebec Soil Survey and total 51,000 acres. Of this area, 27,000 acres were ready for development in 1950, with drainage outlets completed and much of the land favourably situated for controlled irrigation.

The largest single area, which comprises 17,000 acres, is situated in the counties of Chateauguay and Huntingdon, near the village of Ste. Clothilde. Another 10,000 acres lie immediately east of the Ste. Clothilde area, in Napierville county near the town of that name. Both areas border streams that have been deepened to provide drainage. Other smaller areas of from 500 to 5,000 acres are situated in the same general area. The entire region is well served by good roads and railroads, and most of it is within 50 miles of the city of Montreal. Other cities and towns are within easy shipping distance.

The climate of the region is ideal for vegetable crop production. Normal precipitation is from 35 to 40 inches a year and monthly mean temperatures run from around 50°F. in May and September up to 70°F. in July and August. The frost-free period usually extends from the middle of May until late in September.

At least 80 per cent of the mucklands in these areas are undeveloped and are covered with growth characteristic of the soil reaction and the height of the water-table. Where the soil reaction is near neutral and the summer water level is two or three feet below the surface, the growth is usually cedar, soft maple, poplar, and elm. Where the soil is quite acid, spruce, tamarack, and white birch predominate. On mucks with a high water-table dwarf willow and other low-growing shrubs are found. In the open spaces rushes, sedge, and water-tolerant grasses form the ground cover. On a few small areas where soil acidity is high the cover is largely moss and acid-tolerant shrubs.



Lower: Unimproved muckland, with characteristic cover, near Napierville, Quebec.

Upper: Ground cover of elm, soft maple and poplar, with vigorous shrub growth indicates a muck soil of high quality.

ORIGIN AND CLASSIFICATION

The highly organic soils known as muck and peat are formed by the decay of plant material in the presence of water. They are of varied origin and differ in value to a very considerable extent. The most common type of muck soil in Eastern Canada had its beginning in water-filled depressions where the movement of water was slow. Aquatic plants, such as water lilies and pond weed, grew over these areas and as their life cycle was completed the remains settled to the bottom, thus gradually filling the depressions. As the water became shallow, rush and sedge growth followed and were in turn succeeded by various forms of moss, chiefly sphagnum, where soil and water were decidedly acid in reaction; or by sedge species and water-tolerant grasses, where the reaction was mildly acid to alkaline. Some areas were built up entirely in this manner and form the grass and sedge mucks which are usually of very high quality. Where moss had predominated the resulting soil is often very acid and of relatively poor quality. In other instances there has been a period of tree and shrub growth on these areas following the moss or sedge and grass period which, from the evidence available, was of long duration. Eventually outlets became blocked and flooding killed the forest growth, which was followed by rushes, sedges, and water-tolerant grasses. This has built up a layer of organic matter, which, when decomposed, is of fine texture and excellent quality. Deposits of this type are quite common in the St. Lawrence Valley and the Muskoka district of Ontario. In a number of situations in the St. Lawrence Valley there is evidence that the layer of aquatic origin underlying large areas of muckland has been formed mainly from plants that grew in salt or brackish water. This material is much like gelatine when moist and dries to a hard rubber-like consistency. In some regions it contains large quantities of shells that are obviously those of salt water crustacea. Such deposits are usually highly alkaline but are almost invariably overlaid with neutral or mildly acid layers.

In southwestern Quebec the typical muck deposit of this type may have an aquatic or "jelly" layer up to 10 feet in depth overlaid with three to five feet of partly decomposed forest debris. Over this, and forming the surface layer, there may be up to two feet of well decomposed muck, originating mainly from sedge and grass species. This constitutes a muck soil of very high quality and one on which the most advanced cultural practices can be followed.

Other areas of muck soil have been built up in comparatively shallow depressions without the formation of an aquatic layer. These areas may be composed largely of decomposed material originating from moss, a combination of moss, sedge and grass, or sedge and grass. On such areas the organic layer is necessarily shallow and the reserve of organic matter much smaller than on the deep mucks. In general their value is governed largely by the nature of the underlying soil since as the organic layer becomes thinner, as the result of loss by cultivation, more of the bottom soil will be included in the cultivated section of the profile. Where the bottom layer is a highly calcareous marl the soil may be of little value after the organic layer has been used up. If the bottom is sand it may be retained indefinitely as productive soil by good management. Generally the clay bottom is the most desirable in that muck and clay will form a highly productive and generally desirable soil, when the organic layer has become reduced in depth to a point where cultivation extends into the underlying clay.

Two main groups of organic soils.—Whatever the origin of organic soils, they can be classed in two groups so far as immediate value for agriculture is concerned. These are peat and muck. Peat is partly humified or decomposed plant material, while, with muck, decomposition is practically complete. There are of course all degrees of decomposition in between the two stages and the point where peat changes to muck is obviously obscure. However, it is generally conceded that when decomposition has progressed to the extent that definite plant remains are not easily recognized in an organic soil it may be classified as a muck.

In peat the plant remains are recognizable and the texture of the soil is distinctly fibrous. It has the capacity for absorbing a large quantity of water but aerates readily and during dry weather seldom retains sufficient moisture for crop requirements. Since it is only partially decomposed there is very little available plant food in peat but it may contain up to three per cent of nitrogen in unavailable forms. In order to make soils of this nature productive, decomposition must be speeded up and the soil "activated" by increasing desirable soil microflora. Usually the first step is to provide drainage sufficient to permit normal cultivation. Then, since peat is decidedly low in minerals, particularly potash and some of the minor elements, a liberal application of a fertilizer designed to correct these deficiencies, such as a 2-8-16 with the necessary minor elements, should be applied and thoroughly worked into the soil. This will usually activate a peat soil since useful microflora will increase because the fertilizer in the soil makes it a more favourable medium for them. Moderate to heavy application of lime may also be necessary on decidedly acid peat.

Where the peat is very inactive and surface growth, other than moss, is stunted and poor, or on newly drained areas, it may be necessary to inoculate the soil with the necessary microflora by a moderate application of barnyard manure as a supplement to the commercial fertilizer application. The manure should be well rotted and thoroughly incorporated with the soil. Usually 10 to 12 tons per acre will prove adequate for the purpose. If another application is required it should not exceed 8 to 10 tons per acre since, under normal conditions, in activated organic soil, barnyard manure is unnecessary and even moderate applications may depress crop yields. If virgin organic soil fails to respond following treatment of this nature for two years, and general cultural methods are correct and thorough, it is possible that one or more minor elements are not present in sufficient quantity. Symptoms of such deficiencies and corrective measures are discussed later in the section "Minor Element Requirements of Organic Soils".

Soil Reaction

In general, the most desirable reaction for organic soils is mildly acid with a pH value of from 5·5 to 6·5. This reaction is favourable for most vegetable crops and fixation of plant nutrients is less pronounced than in alkaline soils. Acid soil reaction is also unfavourable to the development of potato scab, a highly desirable condition since potatoes are well suited to muck soils.

Where the pH value falls below 5·0 some correction of acidity is necessary for general crop production. For this purpose lime in some form is necessary and the amount required will depend upon the degree of acidity and the depth of the acid layer. In general, the pH value should not be raised above 6 or 6·5 in the top foot of soil. On shallow mucks which may be underlaid with marl or limestone, one to three tons of ground limestone per acre, well incorporated with the top foot of soil, may raise the pH value from 4·5 to 6. On other areas where the deposit may have been formed from moss, and the subsoil is acid in reaction, applications up to six or seven tons per acre may be necessary. In such extreme cases a two- or three-ton application should be ploughed under to a depth of one foot if possible, and a similar amount applied to the surface and thoroughly worked in. This will correct the acidity to a substantial depth and permit plant roots to function normally well below the surface.

In eastern Ontario and Quebec many crops will grow well on muck soil where the pH value is 5, or slightly less, for a depth of a foot or more. Good crops of potatoes and swede turnips have been observed on muck areas with a pH value of 4·5. Where the pH value is from 5 to 6, onions, spinach, carrots, lettuce, beets, squash, muskmelon, tomatoes and corn can be grown successfully, as well as the more acid-tolerant crops. At this point cabbage, cauliflower, brussels sprouts, and broccoli are satisfactory but celery, a very important muckland crop, prefers a muck soil with a pH value of 6 to slightly over 7. Asparagus, while tolerant of a wide range of soil reaction on muck soil, will produce more abundantly when the soil is near neutral or at a pH value of 7.

Most of the crops mentioned can be grown successfully where the soil is alkaline in reaction, but, as alkalinity increases, production difficulties are greater and the grower must again make a careful selection of crops most tolerant to alkalinity. Of these, celery, carrots, Swiss chard, and parsnips can usually be grown successfully with a pH value up to 8 or higher.

The reduction of alkalinity in muck soil is generally more difficult than the correction of acidity. Applications of sulphur in some form are usually employed for this purpose. The possibility of economically reducing an excess of alkalinity depends both upon the cause of the alkalinity and the origin of the soil. On muck deposits that occur in depressions where the surrounding land is alkaline, or, the native rock is basic, such as dolomite or limestone, the soil may be quite alkaline as a result of residue collected by run-off from the higher land. Under such conditions there may be a relatively high sulphur content in the soil, depending upon its origin, and the application of more of this material may create a toxic condition that will prove difficult to correct. The use of manganese sulphate is often helpful under these circumstances, and amounts up to 200 pounds per acre, in conjunction with sulphur up to 500 pounds per acre, depending upon the degree of alkalinity, have been found effective in some instances. Where the sulphur content of the soil is high, over two per cent sulphur trioxide, as found in a few alkaline mucks in western Quebec, the use of manganese sulphate may bring the soil into a productive state for a number of crops tolerant to alkalinity, such as carrots, parsnips, and Swiss chard. On such soil potatoes, lettuce, onions, radish, and table beets usually cannot be grown successfully. Where the pH value is not above eight and manganese sulphate has been applied, celery will grow successfully if the boron deficiency usually common to such soils is corrected.

Burning is wasteful.—Burning over muck soil to make it temporarily productive will make the top layer alkaline but it is an extremely wasteful practice. The alkalinity is caused by concentrating the minerals from the burned portion, which may be a foot or more in depth, into a few inches. If the underlying layer is acid in reaction the soil can be corrected by deep ploughing so as to mix some acid soil with the alkaline top layer. Deep ploughing for two or three years may be required to bring about the desired condition, but in the meantime alkaline-tolerant crops can be grown. Where the burn has been very deep or the underlying soil is near neutral or alkaline, deep ploughing may not be helpful and applications of sulphur, as suggested above will be found necessary.

While burned-over muck areas may be made productive, with comparatively little trouble and expense, on the whole the practice of burning cannot be too strongly condemned. In the process of burning, the organic matter containing large quantities of nitrogen—as much as three per cent in some mucks—is lost and the ash or mineral matter is left. If a muck area is burned down to a point where the fire is extinguished near the soil water-table, several feet may be thus burned out. This concentrates the mineral matter from the burned portion in a layer over the unburned muck, and, since the soil originally contained too much organic matter and not enough of certain minerals for normal plant nutrition, the soil may become productive if the accumulation of minerals has not been great enough to create excessive alkalinity. In doing this, however, enough organic matter and nitrogen to supply normal crop requirements for a great many years may have been lost. In addition, the alkalinity of the remaining soil may be so high that correcting it to meet crop requirements may be difficult and expensive. A better practice is to apply for each crop fertilizer that will supply the necessary amount of minerals deficient in unburned muck. This will mean that the vast store of nitrogen present in this soil type can be drawn upon as required and the land kept in a productive state indefinitely rather than for the few years possible after burning.

FERTILIZER REQUIREMENTS OF ORGANIC SOILS

Organic soils are high in organic matter, and nitrogen contained therein, but are correspondingly low in essential mineral elements. An analysis that may be considered to be typical of muck soils in Ontario and Quebec, taken from the report of the Quebec Soil Survey Committee, is as follows:

TABLE 1.—ANALYSIS OF MUCK SOIL

—	0″—12″ depth	12″—24″ depth
pH Value	6·27	6·11
	%	%
Total ash	10·70	8·87
Calcium oxide	4·28	3·36
Magnesium oxide	0·72	0·72
Manganese oxide	0·031	0·023
Potassium oxide	0·033	0·019
Phosphoric acid	0·219	0·198
Sulphur trioxide	1·03	1·20
Nitrogen	2·27	1·80

In these soils organic matter, which is the portion other than ash, is often 90 per cent or more of the whole. Total nitrogen is usually over two per cent in the top layer and some essential minerals, such as manganese and potassium, are extremely low. Calcium is usually adequate for crop requirements for a long time and phosphorus is about normal in relation to other minerals. Manganese and other trace elements are required by plants in relatively small amounts and their use is dealt with in another section of this bulletin. Potash, however, is required in relatively large quantities by most crops, and its scarcity in most organic soils is one of the chief limiting factors in crop production.

Potash

In experiments conducted at Ste. Clothilde from 1937 to 1942 with a large number of vegetable crops, increased yields have invariably followed the use of substantial amounts of potash in the fertilizer mixture. This is well illustrated in a replicated trial that was conducted on typical deep muck at Ste. Clothilde, with three vegetable crops, for three years, 1939 to 1941, as shown in Table 2.

TABLE 2.—POTASH REQUIREMENTS OF MUCK SOIL, 1939-1941

Crop	Fertilizer Application per Acre: Nitrogen	Fertilizer Application per Acre: Phosphoric Acid	Fertilizer Application per Acre: Potash	Average Yield per Acre
	%	%	%	Bu.
Potatoes	2	8	0	169·2
"	2	8	8	334·4
"	2	8	16	597·3
Onions	2	8	0	325·3
"	2	8	8	593·1
"	2	8	16	610·1
				tons
Lettuce	2	8	0	10·16
"	2	8	8	11·83
"	2	8	16	13·82

Significant differences (P = ·05) Potatoes 27·9 bushels, onions 11·6 bushels, lettuce 0·39 tons.

With all three crops included in the foregoing table, a highly significant increase was obtained by increasing potash in the fertilizer mixture. With onions, the increase was not so great as with the other crops. In subsequent trials, which are dealt with under phosphorus requirements, potash and phosphoric acid proved to be of about equal importance for onions on the Ste. Clothilde muck soils.

Vegetable crop experiment at the Dominion Experimental Substation, Ste. Clothilde, Quebec.

In addition to correcting the normal deficiency of potash, in most muck soils, additional potash may be required for normal crop development because of the fixation of this nutrient in the presence of a large amount of organic matter.

During the first few years, on virgin soil at Ste. Clothilde, celery plants that had been set in soil heavily fertilized with a high potash fertilizer exhibited symptoms of potassium deficiency in mid August. Under similar conditions where supplementary side applications of muriate of potash were made, this symptom did not appear and the crops developed normally. This was verified experimentally during the four years 1937 to 1940 by comparing celery plots receiving a normal initial application of potash with similar plots receiving supplementary applications, during the growing season.

TABLE 3.—CELERY—SUPPLEMENTARY POTASH APPLICATIONS, 1938-1940

Application per Acre		Average Yield per Acre
Initial 2–8–16	Supplementary Muriate	
lb.	lb.	tons
1,000	0	16·01
2,000	0	22·36
1,000	100	18·75
2,000	100	24·00
1,000	200	18·52
2,000	200	25·22

Significant difference (P = ·05) 1·08 tons.

As production was continued on these soils, with adequate applications of fertilizer high in potash, the need for midseason supplementary applications diminished and at the third year normal crops of celery were produced with initial applications only. With potatoes, onions, carrots, lettuce, cabbage, and probably other vegetables, supplementary applications of potash are of doubtful value even in the first year after breaking. However, with celery when grown on newly broken muck, or where high-potash fertilizers have not been used for several years, midseason applications of about one hundred and fifty pounds of muriate of potash per acre will probably be necessary for the production of maximum crops.

The form in which potash is applied is also important. Because of the normally high sulphur content of some muck soils, fertilizers containing sulphur in appreciable quantity are harmful to certain crops, particularly celery. Experiments conducted from 1938 to 1941, with muriate and sulphate of potash, showed a pronounced drop in yield following the use of sulphate of potash in the fertilizer mixture. This is illustrated in Table 4.

In 1940 potatoes were planted, without further treatment, on the plots where celery had been grown in 1939. On all plots where sulphate of potash had been used the yield of potatoes was below that of the check. In other trials with a

TABLE 4.—CELERY—COMPARISON OF MURIATE AND SULPHATE OF POTASH, 1938-1940

Source of Potash	Application per Acre	Yield per Acre
in 2–8–16 fertilizer	lb.	tons
Sulphate	1,000	12·02
Muriate	1,000	16·00
Sulphate	2,000	14·28
Muriate	2,000	23·62
Check	....	12·80

Significant difference (P = ·05) ·67 tons.

variety of crops on true muck soil, the use of potash in the sulphate form depressed yields except where very small amounts were used. On the other hand muriate of potash has consistently increased yields, except when used in excessive quantities. In the latter case there has been evidence of chlorine injury and a slight drop in yield.

This reaction was emphasized quite strongly in an experiment entailing increasing amounts of potash in the fertilizer application for potatoes. In this experiment an area of the Netted Gem variety received a general application of 2-8-16 fertilizer at the rate of 1200 pounds per acre. After planting of the crop, replicated plots received supplementary applications of 100, 200, and 300 pounds per acre of muriate of potash applied between the rows of crop and incorporated into the soil by normal cultivating and subsequent hilling of the crop. Replicates of the original application were also included as checks. Results are shown in Table 5.

TABLE 5.—INCREASING POTASH APPLICATION IN POTATO FERTILIZER APPLICATION, 1944–1948

Muriate of Potash Per Acre in Addition to Basic Application	Yield of Crop Per Acre		
	Marketable	Unmarketable	Total
lb.	bu.	bu.	bu.
0	328	24	452
100	359	27	486
200	372	22	494
300	291	47	408

Significant difference (P = ·05) 23·4 bushels.

Although the differences in yield in this experiment were not great, it is obvious that on this particular soil, which is typical of the deep muck of the region, there is a definite limit to the use of muriate of potash for the potato crop. Similar results were also obtained with celery, lettuce, spinach, onions, and cabbage. Whether this is because of excessive potash, or the chlorine contained in muriate of potash, has not been determined. However, maximum yields of practically all vegetable crops can be produced on the muck soils of southwestern Quebec with the potash in the fertilizer mixture at or near 275 pounds per acre. As stated, on virgin muck soils supplementary applications may be necessary with certain crops, such as celery, for the first two or three years after breaking.

Phosphorus

Although necessary in fertilizer applications to muck soils, phosphorus is secondary to potash in importance for most vegetable crops. Notable exceptions are onions, beans, peas, and tomatoes. In a large number of trials at Ste. Clothilde phosphorus proved to be about equal in importance to potash for these crops. In an experiment which included six vegetable crops, three different levels of nitrogen, phosphorus, and potash were applied in all possible combinations. The only significant result in favour of phosphorus was with the onion crop. This is shown in Table 6.

In this experiment phosphoric acid proved to be effective with onions in amounts up to 240 pounds per acre when used with moderate amounts of nitrogen and potash. With the heavier applications of phosphorus both stand of crop and maturity were improved. Similar results have been obtained with beans, peas, and tomatoes. With other crops, including potatoes, celery, carrots,

TABLE 6.—PHOSPHORUS LEVELS IN THE FERTILIZER FOR ONIONS
1939–1941

Pounds of Nutrients per Acre			Marketable Onions per Acre
Nitrogen	Phosphoric Acid	Potash	
			bu.
30	0	120	502·3
30	120	120	726·5
30	240	120	742·5
30	120	240	746·5
30	240	240	820·5
60	120	240	733·0
60	240	120	758·0
60	240	240	903·2

Significant difference (P = ·05) 39·2 bushels.

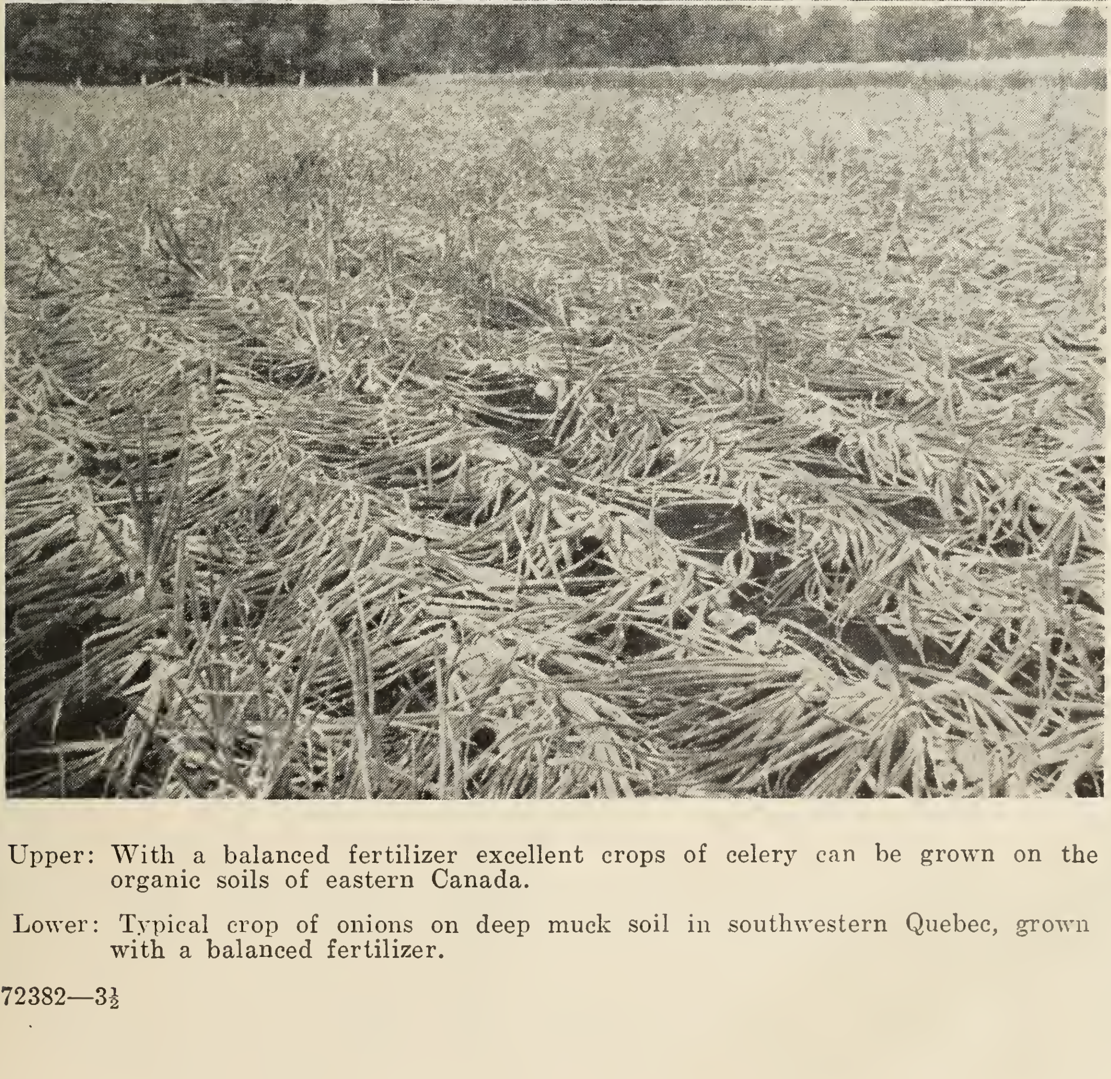
cabbage, lettuce, spinach, and broccoli, maximum yields may be obtained when the phosphorus, as phosphoric acid, is present in the fertilizer mixture at one-half the amount of potash. In larger proportions it has depressed yields of most crops and increased bolting of celery and spinach at Ste. Clothilde.

Nitrogen

Organic soils contain relatively large amounts of nitrogen, some areas in southwestern Quebec having up to three per cent on a dry-matter basis. However, this nitrogen is largely unavailable and is drawn on only as converted to available forms by the action of microflora. These organisms need a balance of nutrients, including potash, phosphorus, and other mineral elements, in order to live and function. Accordingly, in uncultivated and newly broken muck soils, or where the soil is only partially decomposed, the release of nitrogen may be too slow for crop requirements.

In the early part of the season when soil temperatures are low, available nitrogen is often present in very small amounts. Later in the season, when the temperature is high enough to promote microflora activity, nitrogen becomes available from the soil. If other nutrients are present in correct balance and the amount of soil moisture is satisfactory, sufficient nitrogen is usually made available for crop requirements until the end of the growing season. However, for crop requirements early in the season some available nitrogen must be supplied to promote growth up to the beginning of warm weather. On partially decomposed peat soils the action of microflora is usually slow and the release of nitrogen inadequate for normal crop growth. Accordingly, moderate amounts of nitrogen are necessary in the fertilizer application to augment that released from the soil throughout the entire season. A similar condition may also prevail on newly broken muck soil or soils that have been drained recently.

In general, with normally activated muck soil applications of nitrogen, above that required as a starter, are of little value and may be detrimental. At Ste. Clothilde various levels of nitrogen in the fertilizer application have been tried with the principal vegetable crops over the five-year period, 1938 to 1942. These trials have shown clearly that while moderate applications of available nitrogen up to 20 or 30 pounds per acre are beneficial to most crops, larger amounts are detrimental. This is well illustrated in Table 7 which covers an experiment with potatoes extending over the five-year period, in which three levels of nitrogen were used with constant phosphoric acid and potash.



Upper: With a balanced fertilizer excellent crops of celery can be grown on the organic soils of eastern Canada.

Lower: Typical crop of onions on deep muck soil in southwestern Quebec, grown with a balanced fertilizer.

TABLE 7.—NITROGEN LEVELS IN POTATO FERTILIZERS, 1938-1942

Nutrients Per Acre			Yield Per Acre of Marketable Crop
Nitrogen	Phosphoric Acid	Potash	
lb.	lb.	lb.	Bu.
0	0	0	261
20	0	0	257
30	0	0	223
40	0	0	185
0	80	160	388
20	80	160	408
30	80	160	397
40	80	160	327

Significant difference ($P = \cdot 05$) 19·3 bushels.

Similar results were obtained with carrots, lettuce, spinach, green beans, cabbage, and onions. With celery, increased growth and weight of crop were obtained with nitrogen up to 60 pounds per acre in a 1200-pound application of fertilizer. However, the keeping quality of the celery was reduced and susceptibility to black heart increased.

In seasons that are characterized by wet, cool weather, soil nitrification may be slow and the release of available nitrogen inadequate for normal crop growth. During the past ten years this seasonal condition has occurred twice at Ste. Clothilde and a number of observational trials were conducted with carrots, cabbage, broccoli, potatoes, and celery. With each crop, growth was substantially increased and higher yields obtained following the use of a supplementary application of 30 to 40 pounds of nitrogen per acre, which, with the initial application, made a total of 50 to 60 pounds of this nutrient per acre. However, this treatment is advisable only under abnormal conditions; on activated muck soil in a normal season it would cause a reduction in quality or yield of crop.

With most vegetable crops on well decomposed muck soils the amount of nitrogen in the fertilizer, as indicated by experiments at Ste. Clothilde, should be about one-eighth that of potash and one-quarter that of phosphoric acid.

Method of Applying Commercial Fertilizers

The method of applying commercial fertilizers is highly important for its effective use in organic soils. Because of the great capacity of these soils to absorb water and their open, fluffy texture, which permits free aeration with rapid drying out, summer rains seldom penetrate more than a few inches and this moisture is soon lost by evaporation. Accordingly, plant roots do not develop, under normal conditions, within two or three inches of the surface and fertilizer placed near or on the surface can be carried to them only by abnormally heavy rains. It is obvious, therefore, that fertilizers must be placed at a depth where the soil remains moist so that nutrients are dissolved in soil moisture, and thus made available where the roots of plants are located.

From 1938 to 1948 at Ste. Clothilde extensive experiments were conducted with seven vegetable crops involving various methods of fertilizer placement. The first of these was a comparison of harrowed-in broadcast applications and the standard row-placement method in which the fertilizer was placed in bands on either side of, and slightly below, the seed. The broadcast applications were thoroughly mixed with the soil to a depth of four or five inches. This experiment was conducted for three years with six vegetable crops on a deep, well decomposed muck where the water-level in the ditches was maintained at about 20 inches from the surface throughout the season. During most of the growing period, in each year, the top two or three inches of soil was relatively dry, with ample moisture available below that level, and increasing to complete saturation at about twenty inches. Four different formulae were used in this experiment and they were applied at two different rates. All treatments were replicated and the plots randomized. Table 8 shows the average of results of all formulae and rates.

TABLE 8.—BROADCAST vs. ROW PLACEMENT OF FERTILIZERS, STE. CLOTHILDE, 1938–1940

Crop	Method of Application	Yield Per Acre	Increase
		lb.	lb.
Head Lettuce	Row Placement	37,131	
"	Broadcast	42,136	5,105
Spinach	Row Placement	15,652	
"	Broadcast	15,780	0,128
Potatoes	Row Placement	20,432	
"	Broadcast	24,726	4,294
Onions	Row Placement	41,800	
"	Broadcast	43,943	2,143
Carrots	Row Placement	54,137	
"	Broadcast	67,103	12,966
Cabbage	Row Placement	49,090	
"	Broadcast	49,423	467

Although the difference in results with cabbage and spinach was not quite enough to be significant, the superiority of a deeply-worked-in broadcast application is highly significant with four important vegetable crops. The apparent reason for this is that in muck soil, which is loose and open, root development is both rapid and extensive. Accordingly, fertilizer at a distance of a foot or more from the seed may be reached by roots in a shorter time than would be the case in mineral soil. In addition, where fertilizer is laid down in two narrow bands the concentration of nutrients in the soil may be too high at that point and cause injury to some of the roots.

However, with broadcast applications harrowed in, some of the fertilizer remains in the inactive top layer of soil where it cannot be utilized by plants. This observation led to trials with potatoes and carrots of various methods of fertilizer placement below the surface. The results of these trials, conducted for four years, 1943 to 1946, are shown in Table 9.

TABLE 9.—PLACEMENT OF FERTILIZERS. STE. CLOTHILDE, 1943-1946

Crop	Fertilizer per Acre	Application		Yield of Crop per Acre
		Method	Depth	
	lb.		in.	tons
Carrots	600	Broadcast	0–5	21·31
	1,200	"	0–5	29·47
	600	Plough sole	4	27·43
	1,200	"	4	30·08
	600	"	8	26·41
	1,200	"	8	29·82
	600	Grain drill	4	28·73
	1,200	"	4	32·80
Potatoes	800	Broadcast	0–5	11·63
	1,600	"	0–5	12·08
	800	Plough sole	4	12·91
	1,600	"	4	14·93
	800	"	8	12·87
	1,600	"	8	15·06
	800	Grain drill	4	13·18
	1,600	"	4	16·13

In this experiment yields were consistently high, none of the methods giving poor results. However, the grain drill method whereby the fertilizer is placed in bands seven inches apart, at four inches below the surface, is definitely the most satisfactory and can be recommended for a wide variety of crops on organic soils. The plough sole method which places the fertilizer in a band at the bottom of each furrow is not entirely satisfactory in that it entails ploughing for each crop, a practice that is not desirable as explained under the heading "Soil Management".

A combination method, used successfully by a few muckland producers of potatoes, is to broadcast and harrow in two-thirds of the fertilizer and apply the remainder with the standard row-placement equipment on the potato planter. By this method a private grower produced, on average muck soil in 1948 in western Quebec, over 500 bushels of potatoes per acre on a relatively large area with a 1,200-pound per acre application of 2-8-16 fertilizer. At this rate of application the fertilizer in the row-placement bands was not heavily concentrated and probably served as an efficient starter for the crop during early growth. Later, as root growth developed, the broadcast application over a wider area was sufficient for crop development. This method will probably be used extensively for potatoes on organic soils, but for many other crops the grain drill method of application seems to be the most desirable.

Use of Barnyard Manure

In general the use of barnyard manure as fertilizer for muck or peat soils is likely to prove detrimental rather than useful. On newly broken, recently drained land, or inactive peat, the application of small quantities of barnyard manure along with commercial fertilizers, balanced to correct deficiencies, will serve to inoculate the soil with useful microflora and establish conditions favourable for their growth. After this has been accomplished barnyard manure applied to muck or peat adds organic matter to soil already containing up to 90 per cent or more of this material. This is obviously unnecessary, and on the well decomposed mucks in southwestern Quebec 10 tons of barnyard manure has proved inferior to 1,000 pounds of 2-8-16 fertilizer. This effect was demonstrated quite conclusively in an experiment conducted at Ste. Clothilde with four vegetable crops over a four-year period. In this experiment barnyard manure gave a slight increase in yield with two crops and a loss with two others, in comparison with the check.

TABLE 10.—COMPARISON OF BARNYARD MANURE AND COMMERCIAL FERTILIZER ON MUCK SOIL, STE. CLOTHILDE, 1937-1938

Crop	Yield per Acre		Check No Manure or Fertilizer
	Manure, 10 tons	2-8-16, 1,000 lb.	
	lb.	lb.	lb.
Potatoes	19,260	28,473	20,438
Onions	25,950	44,500	22,905
Cabbage	36,440	54,107	31,063
Spinach	8,417	14,041	8,024

In some instances on shallow muck areas that have been under cultivation for a long period, barnyard manure can be used profitably, since the organic matter on such soils has become depleted to some extent and trace elements contained in the manure may be deficient. Also, combinations of barnyard manure and commercial fertilizer have been found profitable on peaty soils where the release of plant food is slower than in well decomposed muck. However, under average conditions barnyard manure is not a satisfactory fertilizer for organic soils.

MINOR ELEMENT REQUIREMENTS OF ORGANIC SOILS

Since organic soils are composed largely of organic matter they contain a relatively small amount of minerals and are correspondingly low in the so-called minor or trace elements necessary for the balanced nutrition of plants. For a period of five years, 1937 to 1941, a number of trials were conducted at Ste. Clothilde dealing with the requirements of minor elements for vegetable crops on the typical deep muck soils of the area. From these trials, and observation on other areas, it was found that boron, copper, and manganese were the most commonly deficient and that a positive response was obtained following the application of one or more of these elements with a wide variety of vegetable crops. Sulphur was included in this trial in order to study its reaction in crop response on this soil type, which is normally high in this element. However, sulphur is not, correctly speaking, a minor element since it is used in relatively substantial quantities by plants.

A summary of these trials is shown in Table 11. The several elements were included with an otherwise balanced fertilizer, and the plus or minus signs indicate a difference in yield of 10 per cent or more.

TABLE 11.—EFFECT OF MINOR ELEMENTS ON VEGETABLE CROP YIELDS, 1937–1941

Crop	Basic Fertilizer		Reaction to Minor Elements Added			
			Boron	Copper	Manganese	Sulphur
	lb.	per acre				
Carrots	800	2- 8-16	+	+	0	—
Cabbage	1,000	2- 8-16	+	0	+	—
Celery	1,500	2- 8-16	+	+	+	—
Bean (snap)	700	2-10-12	+	+	+	—
Lettuce	1,000	2- 8-16	0	+	0	—
Onion	1,000	2-10-12	0	+	0	—
Potato	1,500	2- 8-16	0	0	—	—
Spinach	800	2- 8-16	+	+	+	—

Copper

Of these four elements, copper, as indicated in Table 11, is required by most crops on the muck soils of southwestern Quebec. In no instance has it suppressed yield and it is probable that with potatoes a positive result would have been obtained if copper compounds had not been very freely used in spray applications to this crop for the control of late blight. For onions, it is apparently an absolute necessity if satisfactory skin colour and maturity are to be obtained. Without copper, yields are often depressed as much as 30 per cent and the crop is of inferior quality. The deficiency symptoms of this element are not easily recognized in onions in the early stages of growth unless the deficiency is pronounced. It then causes an unnaturally erect, somewhat dwarf growth, with dieback of leaf tips, which turn light grey in colour. At maturity the skin of the onion is thin and dull in colour.

On the muck soils of eastern Ontario and western Quebec moderate to severe deficiencies of copper can be corrected with applications of 30 to 50 pounds of copper sulphate per acre applied with the fertilizer. In other regions applications up to 100 pounds or more per acre have been found necessary by some growers.

With celery, the use of copper in the fertilizer mixture is of doubtful value since under ordinary conditions the crop must be sprayed heavily with copper compounds to control disease. In general, it may be advisable to include copper sulphate up to 30 pounds per acre in the fertilizer application for the first year that celery is to be grown on newly broken land, or where copper has not been used in spray or dust applications on preceding crops. Otherwise the residue from spraying or dusting will provide a sufficient quantity of this element for crop requirements.

Copper deficiency depresses yields and lowers the cooking quality of carrots and beets. Colour is also affected, particularly in carrots. When these are grown on copper-deficient soil they fail to develop the bright orange-yellow colour, characteristic of a good quality carrot. Spinach and lettuce are also susceptible to a deficiency of this element and develop a dull or faded green colour instead of the bright green of normal lettuce and the deeper healthy green of well grown spinach. With such crops applications of 40 to 50 pounds of copper sulphate per acre seem to be sufficient on most of the muck soil areas of Eastern Canada.

Although beans are not generally critical of copper deficiency, on the muck soils of southwestern Quebec there has been a consistent positive response to applications of copper sulphate. These applications have been at rates of 20 to 40 pounds per acre and have increased yields of snap beans up to 20 per cent. This was particularly noticeable on shallow or very dry muck, which, if there is a choice, is the location usually preferred for the growing of this crop on muckland farms.

In general, copper deficiency has been observed largely on acid muck soils and is seldom severe in soils having a pH value higher than 7·0. Crop response to this element is also more pronounced during warm weather when precipitation is relatively low.

Boron

As indicated in Table 11, a wide variety of crops have responded to applications of boron at Ste. Clothilde and elsewhere on muck soils in Eastern Canada. Deficiencies of this element are somewhat more common on muck soils that are neutral or alkaline in reaction but, although less common on acid mucks, are sometimes severe and responsible for heavy crop loss. Probably the greatest loss due to boron deficiency is with celery. On this crop the symptoms are the characteristic "cracked stem", or "cat scratches", on the petiole or leaf stems of the plant. These are caused by the breaking of the ribs in the stems. With a slight or moderate deficiency extra stripping, with a consequent reduction of marketable crop, is necessary, while in severe cases the entire crop may be lost. In storage experiments conducted with muckland celery at the Horticultural Division, Central Experimental Farm, Ottawa, in 1938-39, it was found that even a very slight boron deficiency adversely affected keeping quality. It has also been observed at Ste. Clothilde that a crop grown where there is no deficiency of boron is less susceptible to the physiological disorder known as "black heart" than one grown where such a deficiency exists.

Under average conditions an application of 15 to 20 pounds of borax applied with the fertilizer is sufficient to correct soil deficiency of boron for celery. In severe deficiencies at least one application up to 50 pounds has been found necessary. However, because of the toxic action of excessive boron in the soil, it is not advisable to exceed this amount in a season, and, as soon as deficiency symptoms can no longer be found in the celery crop, the borax application should be reduced or discontinued until its need is again apparent.

Where symptoms of boron deficiency develop on the growing crop, very satisfactory results can be obtained by including four to five pounds of borax per 100 gallons in one or more of the regular sprays for disease and insect control. This will usually prevent the development of further injury and subsequent growth will be normal. However, petioles that have already developed symptoms will not recover and must be stripped off at harvest.

Beets and carrots are often severely damaged by boron deficiency. This is indicated by horizontal or ring cracking of beets and longitudinal cracking of carrots, both of which render the roots unfit for sale. Turnips, particularly Swede turnips, when grown on boron-deficient muck soil develop brown-heart, a darkening of the center of the root, which when cooked is stringy and unpalatable. Boron-deficient cabbage and spinach plants are undersized and in extreme cases fail to develop into normal plants. With beans, yields are depressed and the pods toughen abnormally early. At Ste. Clothilde tomatoes have also been affected by boron deficiency, which has decreased yields, induced the characteristic symptoms of brittle leaves and stems, and caused the terminal growth to die. Increased yields of sugar beets have been obtained following application of borax.

For all of the crops mentioned above, except beans, soil applications are the most effective in correcting boron deficiency in the soil. Borax can be used annually in the fertilizer application at 10 to 15 pounds per acre, or applied every second or third year at rates up to 30 to 40 pounds. Seldom, if ever, will it be found necessary, on the muck lands of Eastern Canada, to use quantities in excess of this amount. Should it be apparent that a higher application is required the need should be definitely determined by soil or tissue analysis, and expert advice obtained as to the amount required. Beans are critical in their response to boron and a small surplus in the soil may have a toxic effect. Accordingly, where deficiency symptoms occur, it is probably safer to take a possible small loss for that season and apply five or six pounds of borax per acre to the soil, or three to five pounds in a spray on the crop when it is about half grown.

Applying boron to the soil as borax in solution is a convenient and effective method that has been employed successfully at Ste. Clothilde. The required amount of borax is dissolved in water and applied to the soil with a weed boom on an ordinary row-crop sprayer. By this method a very even distribution is obtained and this work can be done cheaply and quickly.

Manganese

Manganese, which has shown positive results with four of the eight crops listed in Table 11, is important as a minor element in the formation of chlorophyll. It is present in very limited quantities in the muck soils of Eastern Canada, and deficiency symptoms have been observed on a wide variety of crops on several areas. Elsewhere there seems to have been enough of this element available to meet normal crop requirements to date in spite of the small quantity present in the soil. This may be explained in part by the fact that the presence of manganese as an impurity in fertilizer was quite common some years ago. However, with the modern trend towards higher analysis fertilizers, which contain fewer impurities, less manganese is available from this source and its need may become more apparent as cropping of muckland continues.

In general, muckland soils that are neutral or alkaline in reaction are more commonly deficient in manganese, although the deficiency also occurs occasionally on acid mucks. At Ste. Clothilde, where the soil reaction is mildly acid, potatoes, celery, spinach and beans have responded to applications of manganese sulphate. With celery in particular, its use appears to be necessary for the development of good clear colour in yellow celery and as an aid in resisting "black heart".

The general symptom of manganese deficiency is a pale mottling of the leaves with a lighter than normal green colour. Yields of all affected crops are reduced and there is a distinct drop in the quality of spinach, celery, and snap beans.

In western Quebec the deficiency of this element has been consistently corrected by application to the soil of manganese sulphate, up to 50 pounds per acre, applied every second or third year. With celery and potatoes, deficiency can be controlled when it appears by including manganese sulphate in one or more of the regular bordeaux or fixed copper sprays at the rate of five or ten pounds per 100 gallons.

Sulphur

Although sulphur, which plants use in larger quantities than the so-called minor elements, has been found beneficial on certain areas of mucklands in the United States, no large areas have been observed in Eastern Canada where its use seems to be necessary. This is probably due in part to the reaction of these mucks, which are seldom alkaline, and to the normally high sulphur content commonly found over large areas of this soil type. At Ste. Clothilde, as shown in Table 11, moderate applications of sulphur have depressed yields of celery, beans, and lettuce, and have a similar effect by residual action on succeeding crops for two or three years. Even fertilizers containing sulphur in chemical combination may prove harmful as indicated in Table 4 under "Fertilizer Requirements of Organic Soils".

On the relatively small areas of alkaline muck, or on burned-out areas, applications of sulphur up to 1,000 pounds per acre have proved beneficial. However, before such applications are made the pH value of the soil should be determined and technical advice obtained as to the application of the sulphur required.

Common Salt

Common salt (sodium chloride), although beneficial on many of the muckland areas of North America, has not been found necessary on the muck soils of western Quebec or eastern Ontario. Applications of salt at 500 pounds per acre, made to six vegetable crops at Ste. Clothilde, produced negative results. In another trial with sugar beets and spinach a very slight response, which was not significant, was noted.

Zinc

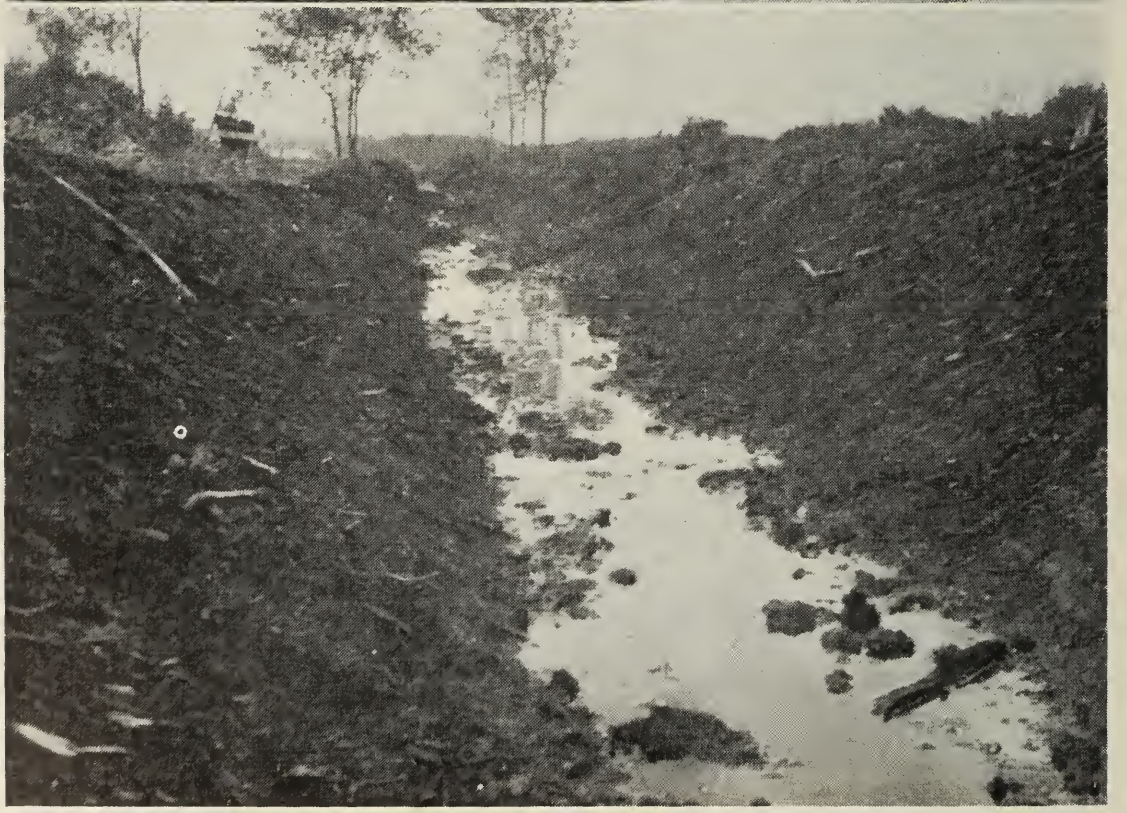
Zinc in the form of zinc sulphate, has been tried at Ste. Clothilde, with all the common vegetables for three years, but without encouraging results. With potatoes, a slight increase in the vigour of the tops was observed, but the increase in yield was negligible with applications of 25 pounds per acre. Heavier applications depressed yields. Beets, carrots, beans, and spinach were not affected, while yields of lettuce and onions were lowered.

WATER CONTROL

The control of water in organic soils at a point where it is satisfactory for plant growth is one of the most important factors in successful crop production. This type of soil has a very high moisture-holding capacity, well decomposed mucks holding up to one and one-half times their weight of water and semi-humified peat often more than double its weight. The point at which plant roots cannot secure water from these soils is also high. In experiments conducted in the greenhouse at the Central Experimental Farm, Ottawa, with well decomposed muck from the Ste. Clothilde Substation, it was found that celery wilted when the moisture content of the soil was lower than 60 per cent. On the other hand the first wet-soil symptom appeared on the celery when the soil moisture content was between 95 and 100 per cent. This will, of course, vary with different soils. Marginal muck, containing up to 25 or 30 per cent of mineral materials, would become saturated at 60 or 70 per cent moisture and require less water for crop growth than the deep mucks of eastern Ontario and southwestern Quebec, where the mineral content is only nine or ten per cent. Peats, with their very high moisture-holding capacity, may not release water to plant roots until the moisture content is over 100 per cent. Accordingly the high moisture-holding capacity of organic soils usually prevents normal summer rains from penetrating deeply enough to supply moisture for plant roots and, because of the open texture of the soil, this moisture is soon lost by evaporation. It is obvious, therefore, that although these soils hold a large amount of moisture, correspondingly large quantities may be required for plant growth, if applied to the surface, because of rapid loss. Summer rains are usually inadequate for the requirements of these soils in Ontario and Quebec, and to obtain maximum production of most of the vegetable crops in average seasons, additional water must be provided.

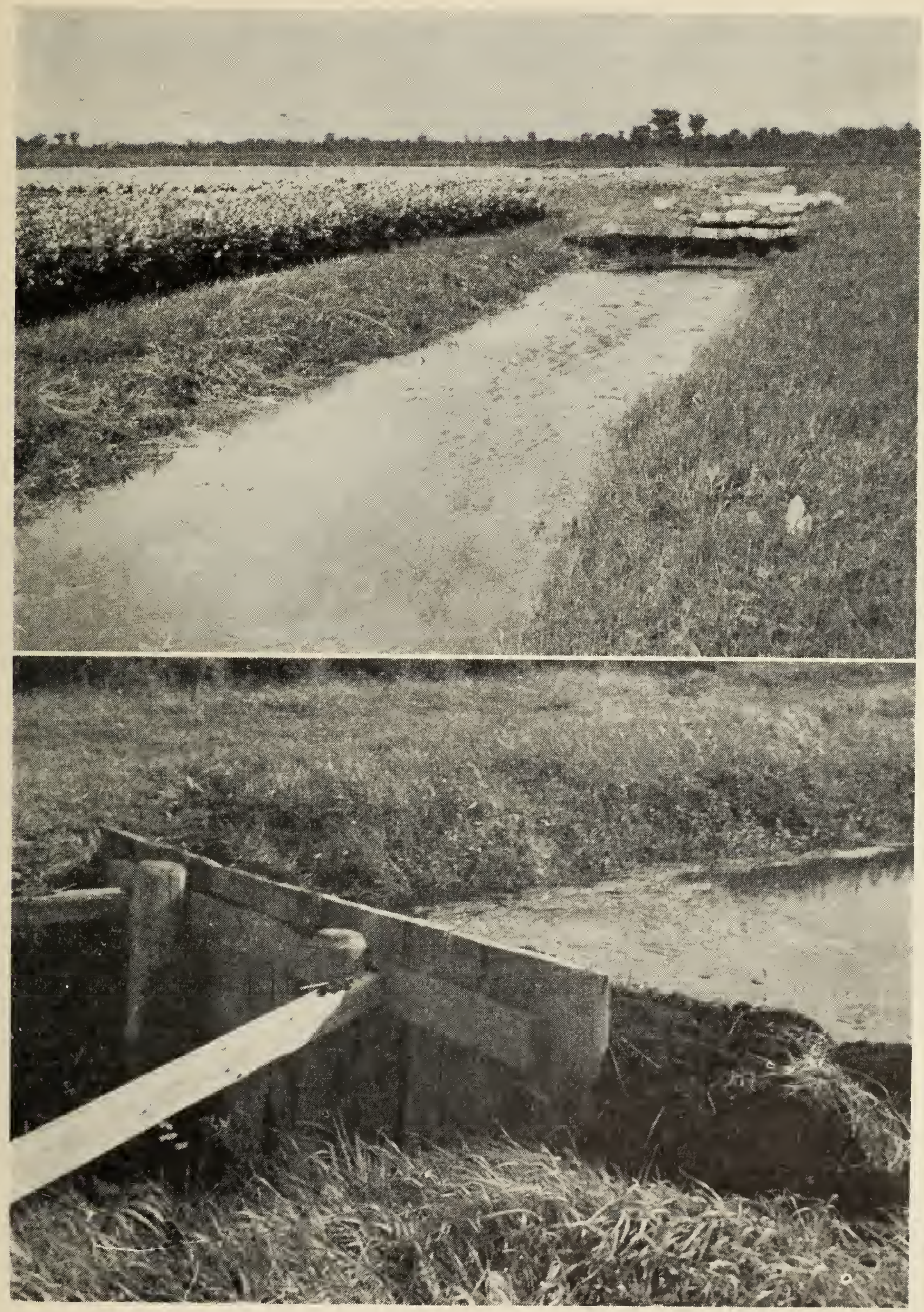
In many of the typical deep muck areas of the St. Lawrence Valley the soil profile and the location are ideal for water control. Most of the principal areas are along streams where water is available for irrigation, and drainage can be obtained by deepening the streams. The typical formation consists of a lower layer of aquatic muck overlaid by forest debris, which is in turn covered by a well decomposed layer, originating largely from sedge and grass species. Usually the aquatic layer is situated four to five feet below the surface. It is gelatinous in character and while it will absorb water very little will pass through it. The layer of forest debris or wood muck is more or less open in texture, containing a high percentage of only partially decomposed limbs and trunks of trees. Lateral seepage of water through this layer is quite rapid, and, since it overlies a practically water-tight layer of aquatic muck, it can serve to carry water either for drainage or irrigation. Above this the sedge grass layer is usually in an advanced stage of decomposition and of fine texture. When moist, it can be compacted so that water rises through it by capillary action. By digging ditches so that they penetrate into the forest muck layer, and have a satisfactory fall to the outlet, surplus water can pass readily through the open texture of this layer and thus provide drainage. When water is required for irrigation it can be pumped back into the ditches, and held at the desired levels by dams so constructed that the water-level can be regulated. This water-level will depend to some extent on the kind of crop grown, but, if the porous layer is saturated up to the bottom of the fine-textured surface layer, water will move up into the plant root zone. If the bottom of this surface layer is kept moderately compact, the upward movement of water is greatly facilitated and its regulation for crop requirements comparatively easy. If more water is needed, the level in the supply ditches can be raised and if less is required it can be lowered. When drainage is required to take care of extremely heavy precipitation during the growing season, to move off surplus water in the spring, or to dry up the land and hasten the maturity of crops, the dams can be opened and the ditches will serve equally well for drainage.

When ditching in muckland underlaid with aquatic muck it is advisable, if at all possible, to keep the bottom of the ditches about one foot above this lower layer. Aquatic muck is gelatinous in texture and when saturated with water resembles thin gelatine pudding. If when digging a ditch this layer is uncovered, the pressure of the surrounding soil will cause the aquatic muck to ooze up into the ditch until it is filled to near the surface. This may be dug out, but it is a difficult operation with this type of material, and the muck will fill in again unless sealed off.



Upper: A swamp will become productive. Part of the huge acreage of organic soil in the St. Lawrence Valley in process of development.

Lower: In well decomposed organic soil ditch banks must have a pronounced slope.



Upper: A ditch fitted for seepage irrigation of muck soil.

Lower: A cheap but efficient dam to hold back water for seepage irrigation.

Usually the aquatic layer is situated sufficiently deep to permit the digging of ditches and drains to a depth adequate for drainage and irrigation, which is normally from two to three feet. However, under certain conditions such as on large bogs, where it is necessary to dig part of the main ditches relatively deep in order to get sufficient fall for drainage, or on areas where the aquatic layer is situated close to the surface, ditches may penetrate this layer. Where this occurs a plank drain of sufficient size may be laid in the aquatic muck and the ditch filled in to hold it in place. It is essential that such drains be made tight to prevent aquatic muck from leaking into, and eventually blocking them. It is also important that they be made strong and rigid to prevent them from sagging in the soft bottom. To help prevent sagging over long stretches, pieces of plank four to five feet long can be laid at right angles under the drain every 15 or 20 feet.

Another method, which has been used successfully at the Ste. Clothilde Substation, is to seal off the aquatic muck in ditch bottoms by lining the exposed gelatinous layer with a plank trough. The trough can be held in place by weighting it with stones or by driving short stakes horizontally into the fibrous layer, above the aquatic layer. The advantage of this method is that the trough in the ditch bottom can be cleaned easily and the level of the bottom adjusted when necessary without having to re-dig the ditch.

At Ste. Clothilde covered drains of various types have been tried. These include perforated fibre pipe, several types of plank drains, and ordinary land tile laid on boards to prevent uneven settling. These have been only partly successful. The very fine particles of well decomposed muck find their way into land tile and perforated pipe drains so that they usually become plugged in a few years. Plank drains with the opening at the bottom have seldom become plugged, but, even when made very strong and rigid, they get out of alignment following winters when frost penetrates deeply into the ground.

For irrigation, the underground drains have not proved so satisfactory as open ditches. Water-levels are not easily determined or controlled, and uneven irrigation is often unavoidable because of the blocking or settling of the drains. With open ditches, water-levels can be determined at a glance and the flow into the ditches is easily adjusted to meet requirements.

Open ditches are also more reliable for drainage since they have greater capacity than underdrains and can be cleaned at less expense. On the other hand they occupy land that could otherwise be cultivated, and ditch banks usually become infested with weeds which must be kept mowed, or otherwise suppressed, to prevent them from seeding and spreading to cultivated areas.

On organic soils where the surface layer is well decomposed and will become loose and crumbly when dry, ditches should be dug with sloping sides so that they will not fall in or the soil slip and block the ditch. At Ste. Clothilde Substation the required slope proved to be about 45 degrees. On other areas where the soil is composed of peat, particularly that originating from sphagnum moss, ditches can be dug with vertical banks as the fibrous composition of the peat holds the sides firmly and a slip-in or cave-in rarely occurs. Where it is necessary to have sloping ditch banks, seeding the slope to grass will save a great deal of time and trouble in controlling weeds and will prevent erosion during heavy rains or run-off periods. The kind of grass to use can be determined by observing the species that grow naturally on similar situations in the neighbourhood. In general, red top (*Agrostis palustris*) or reed canary grass (*Phalaris arundinacea* L.) will be found suitable over a wide range of conditions. Seed of both is readily obtainable commercially. Both are acid-tolerant, perennial, and spread by underground root stalks. On areas of organic soil, where the reaction is neutral or mildly alkaline, Kentucky blue grass (*Poa pratensis*) usually grows naturally and is ideal for holding ditch banks.

The amount of water required by organic soils in addition to normal rainfall, will vary with conditions and soil types. Occasionally well decomposed muck soils overlie clay in a depression where there is little or no drainage and are too wet for successful crop production. Often with moderate drainage such sites may become dry enough for crop production, yet remain sufficiently moist throughout the season for crop requirements. On other sites surrounded by higher land, where run-off water is plentiful after heavy rains, sufficient water for irrigation may be held in the ditches by dams that can be built to overflow at the level at which the water-table should be held in the soil. On other sites that are situated at or near the water-table level or that border streams or lakes where water is held back by dykes, surplus water must be pumped from the land. Under these conditions the regulation of the water supply is simple since, when required, it can be run into the ditches by gravity or pumped out of the same ditch system when the water-table gets too high.

However, most of the muck and peat areas in Ontario and Quebec are situated along streams or lakes where the normal water-table is somewhat lower than the surface of the land. Under such circumstances water for irrigation must be pumped back into the ditches when required. The amount of water necessary for normal crop requirements depends largely upon the kind of crops grown. At the Ste. Clothilde Substation a record has been kept of the volume of water pumped for irrigation during ten seasons, 1937 to 1946. This has amounted to approximately 14,000 gallons per acre per week from the middle of June until the second or third week in August for all crops. Certain crops, such as potatoes, beans, spinach, cabbage, and onions, require less added water and have produced normally with irrigation at the rate of 8,000 to 10,000 gallons per acre per week. Lettuce, beets, carrots, sugar beets, peppers, muskmelons, and asparagus are normal in their water requirements and have used from 12,000 to 14,000 gallons per acre per week. Celery, tomatoes, and peppermint require more water than most other crops grown at Ste. Clothilde and need up to 15,000 gallons per acre each week during the summer months.

The variation in water requirements between seasons has not been so great as would normally be expected. Surplus water drains off quickly after heavy rains, when the dams in the ditches are opened, and that held in the soil is rapidly reduced by crops and evaporation. Accordingly, rains are very temporary in their effect and do not materially affect the supply to be pumped. In the season of 1943, which was characterized by extremely heavy precipitation, water required for irrigation amounted to 8,000 gallons per acre per week. In comparison, for the season of 1946, which was one of the driest on record at Ste. Clothilde, water pumped to produce normal crops amounted to approximately 15,000 gallons per acre per week.

A difference in water requirements will also be found in different types of muck, and in varying degrees of decomposition of the same type. In general, muck soils originating from grass and sedge are of fine texture, relatively compact, and lose less water by evaporation from the top few inches. Soils formed from forest debris are usually quite open in texture and very light and fluffy. Evaporation from this type of soil is rapid and the saturation point high. Where the deposit is formed from moss the mineral content is often very low, sometimes not more than six or eight per cent, and the water-holding capacity of the soil very high. It is also looser and more open in texture than sedge-grass or wood mucks. More water is required on this soil type before any is available for the use of plants, and loss by evaporation is more rapid. As a result, water requirements for optimum crop production may be as high as 16,000 to 18,000 gallons per acre per week during warm, dry weather.

Where the source of water is below the surface of the land to be irrigated, the water must be conveyed to the highest point and distributed by gravity to the areas where it is needed. At Ste. Clothilde the water is pumped through a fibre pipeline that has proved very satisfactory. This is a standard product used mainly as an underground conduit for electrical wires. It is put together with friction joints, and by actual test can be safely used with pressure up to 15 pounds per square inch if it is placed a foot or more below the surface and the soil is packed firmly around the pipe to prevent bending and stretching. This type of pipe will not corrode, is practically permanent, easily repaired, and much cheaper than metal pipe. Another relatively cheap method for conveying water is by means of elevated flumes or troughs made of wood. However, installations of this type are not permanent and sometimes require extensive repairs.

Fibre pipe line for carrying irrigation water at the Dominion Experimental Substation, Ste. Clothilde, Quebec.

Water can be lifted to a flume or forced into a pipeline with pumps of various types. One of the most satisfactory and efficient is the common centrifugal pump, which will operate satisfactorily for years with very little attention. At the Ste. Clothilde Substation a pump of this type, with a four-inch intake and a three-inch discharge, has supplied water for 40 acres for 13 years, and is still in good condition. It is powered by a five-horsepower gasoline engine and delivers 26,000 gallons per hour. Such a pump, under similar climatic conditions, could provide water for at least 60 acres of muck soil of the same type.

In general, the cost of moving water for the irrigation of typical muck soil deposits is not great. At the Ste. Clothilde Substation, where water is available from a large creek adjoining the property, a record of costs was kept for the ten-year period, 1937 to 1946. This amounted to an average of fifty-nine cents per acre per year for all crops. This figure will, of course, vary considerably with the cost of equipment and supplies and the height of the lift, which at Ste. Clothilde amounted to only 49 inches. Also, equipment and labour were relatively cheap at the time the installation was made. However, it is evident that under a wide variety of conditions irrigation, where needed, can be relatively low in cost.

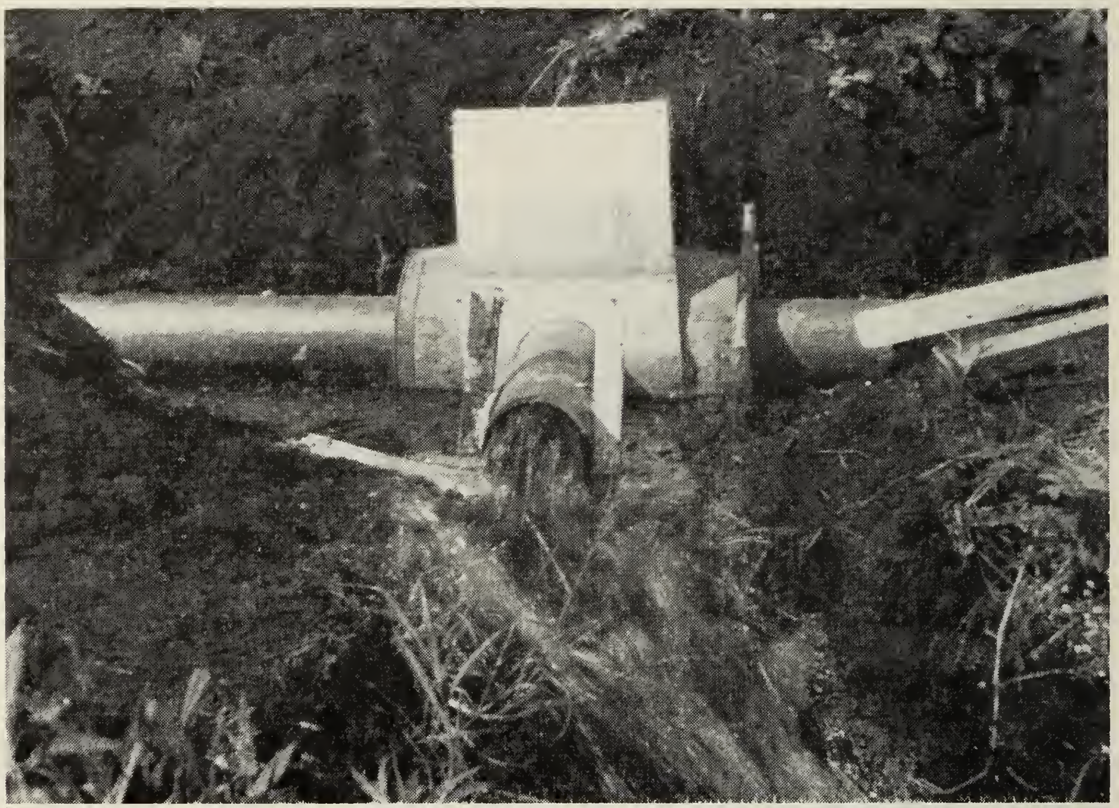
SOIL MANAGEMENT

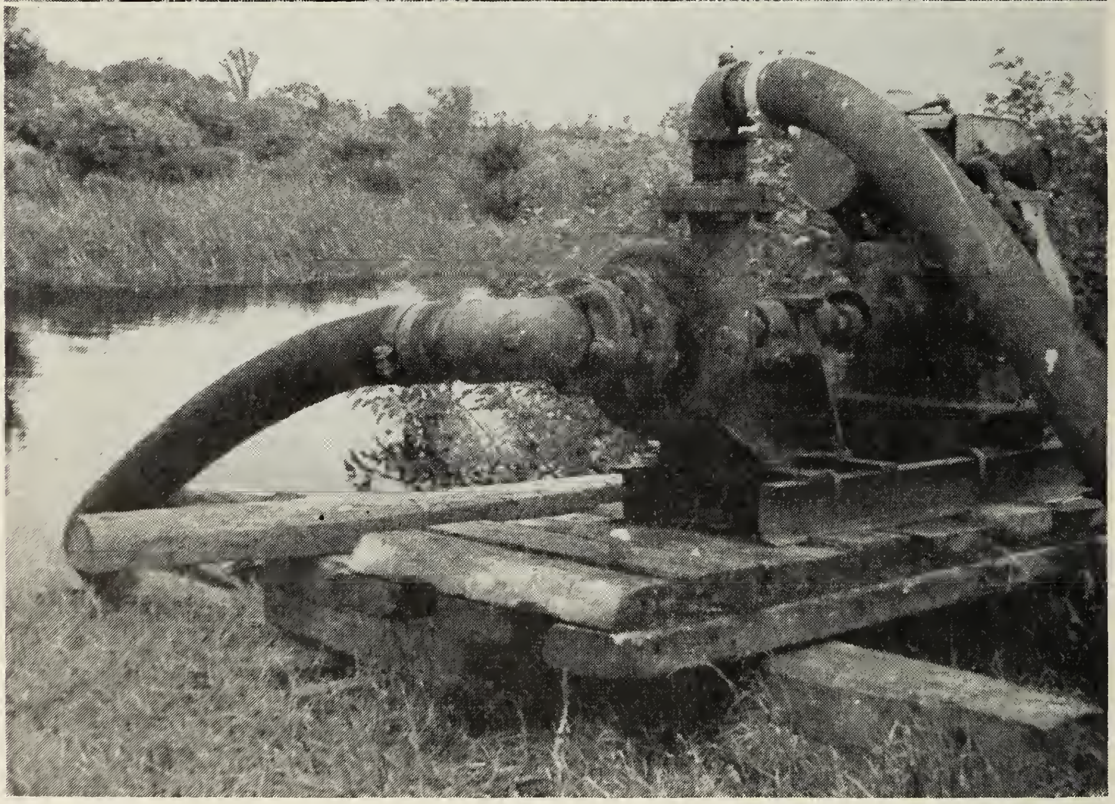
Although ploughing of organic soils may be necessary for some crops and under certain conditions, it is usually unnecessary and under average conditions may reduce crop yields. Because of its light fluffy texture, muck and peat can be easily worked to a satisfactory depth with harrows and cultivators. In addition, it is important to have the lower part of the top layer of soil relatively compact in order to facilitate the upward movement of water by capillary action, and breaking deeply, up to six or seven inches, into the soil with the plough may loosen this layer too much. This would interrupt the upward movement of water and facilitate the drying out of the surface layer to a depth that would leave the moist soil too far from the surface for most crops. Rolling will not always compact this soil to the depth of a plough furrow because of the light rather springy nature of organic soil when moderately dry. As a result a loosened area may be left below the surface through which water cannot rise. Also, since normal rainfall is usually absorbed in the top inch or two, and is rapidly lost by evaporation, ploughed organic soils may remain quite dry to the depth of the furrow during most of the growing season, a condition that is unsuitable for many crops. At Ste. Clothilde it has been observed that, on the ordinary deep muck soils of the area, ploughing the land before seeding is detrimental for onion, lettuce, radish, celery, cabbage, cauliflower, and broccoli. For beans, peas, and potatoes it has little effect. With carrots, parsnips, and Swede turnips it is slightly beneficial. Occasionally if the soil near the surface becomes too compact, which rarely happens on the ordinary muck and peat soils, ploughing to the desired depth may be advisable in order to loosen the soil. Where a portion of the soil profile near the surface contains forest debris that has not decomposed, roots, limbs, and trunks of trees may get too near the surface and interfere with normal cultivation. Where this occurs it is necessary to plough to a depth sufficient to raise these obstructions to the surface so that they can be removed.

After the land has been thoroughly worked and the fertilizer broadcast and disked in, or applied with a grain drill, the roller should be used to compact the soil. This is necessary to close up air spaces in the soil and, by compacting, facilitate the upward movement of moisture by capillary action. The roller should be heavy enough to firm the soil to the depth it has been cultivated, as otherwise movement of moisture will be interrupted.

The weight of the roller will depend up the local conditions. Generally, dry muck soil will require more weight than moist soil. Partly humified peat will not compact so easily as will decomposed muck. Marginal muck, where the organic layer is relatively thin and contains more minerals, can be firmed sufficiently with a light roller. In general, a roller weighing 300 pounds per lineal foot will be adequate for average conditions. If additional weight is required it can be added in the form of weights.

After rolling and before seeding it is a good practice to go over the land with a float or plank drag. This breaks the surface of the soil but leaves the





Upper: A home made water outlet, from a fibre pipe line, for seepage irrigation.

Lower: Irrigation pump at the Dominion Experimental Substation, Ste. Clothilde, Quebec.

Upper: Heavy rollers are required to compact organic soils before seeding.

Lower: The spring tooth harrow will work most organic soils to a satisfactory depth without previous ploughing.

underlying soil firm and compact. Such treatment makes a good seed-bed in which seed will usually germinate better than when sown in deeply loosened soil, or in soil that has been compacted without further treatment.

Seeding

Because the surface inch or two of organic soils dries quickly, and retains very little surplus moisture, germination of seed is generally less dependable than on mineral soils. For this reason seeding rates should be slightly heavier and the seed placed slightly deeper than is advised for other soil types. This is very important with summer seedings, which must be deep enough to place the seed in moist soil otherwise germination will not take place. It is also important, when seeding small seeds that cannot be sown more than an inch in depth, to compact the soil immediately over the seed. This will permit the upward movement of moisture by capillary action at this point and facilitate germination. Usually row-crop seeders are equipped with narrow rollers, which run behind the seed spouts and can be adjusted for additional pressure if necessary.

Cultivation

Cultivation of muck soil is necessary after the emergence of the crop to control weeds and maintain a loosened layer of soil at the surface. Since practically all the moisture for plant growth in this type of soil must come from below the surface, because normal rains do not penetrate deeply, it is important to arrest the upward movement of water below the surface to avoid unnecessary loss by evaporation. Therefore, except where the land is wet, cultivation should be shallow since this layer will be dry, because it aerates readily, and it is not desirable to extend this condition more than an inch or two into the soil. Where the land is wet, as is frequently the case during spring and early summer, deeper cultivation is advisable to facilitate the circulation of air in the top layer of soil and thus hasten drying. Also, in water-logged soil decomposition is arrested and crops may suffer from lack of nitrogen. Aeration of soil in this condition, by cultivation, will bring about conditions favourable for decomposition and will release nitrogen for crop requirements. Later in the season, when surplus moisture has evaporated or drained from the soil, cultivation should be shallow to permit the normal development of roots.

Protection From Wind

Organic soils are light in weight and when dry are easily blown about by wind. Unless these soils are protected by a vegetative cover, losses from wind erosion may be severe. Accordingly, it is good practice to maintain a crop of some sort on the land during the summer months. Where it is not desirable to utilize the land for vegetables, or other saleable crops, plantings of millet, buckwheat, or other grains should be made during the early part of the summer. Since it is unnecessary to build up organic matter on these soils, which already contain up to 90 per cent of this material, growth of these protective crops can be kept to a few inches by occasional clipping with a mowing machine. By doing so the development of seed will be prevented, and the land will be easy to work for planting the next season. Even where the land is to be used for late planting, such as late crops of cauliflower and cabbage, a seeding of oats, barley, or a similar crop in early June is advisable to hold the soil until the desired crop is planted.

On large areas of organic soil, from which wood growth has been cleared, winds may do a great deal of damage to newly emerged seedlings and newly transplanted crops, such as cabbage and celery. Much can be done with both permanent and temporary windbreaks to avoid such damage. Hedges of low

Asparagus as a windbreak for celery.

Radish with Chinese elm as a windbreak.

growing trees, such as Chinese elm, planted along ditch borders are very satisfactory as permanent windbreaks, and their vigorous root systems will also serve to hold the soil on the ditch slopes. Snow fences can be used to good advantage and will cut down the velocity of the wind over a large area. They are easy to move and can be used for the necessary periods in several locations throughout the season.

Certain plants can also be used as windbreaks. For early crops, fall rye planted in narrow strips at right angles to the prevailing wind is very effective. These plants can be sown the previous fall and will usually be sufficiently high by the time early sown crops are germinated to form an effective windbreak. Under most conditions five or six rows, sown with a hand seeder six or seven inches apart, will be satisfactory. Another crop useful for this purpose is asparagus, which grows to near perfection on many organic soil areas. Single or double rows of this crop can be planted where required, and either cropped early in the season and allowed to grow as a protection for late vegetable crops, or left uncut in the spring if early season protection is required. In general the distance at which windbreaks should be spaced depends upon such factors as the usual velocity of the wind, the height of the windbreak, and the amount of protection required by the crop to be grown. At Ste. Clothilde double rows of asparagus have given excellent protection for cabbage, cauliflower, and transplanted onions up to 150 feet. With windbreaks of greater height, such as Chinese elm 10 to 12 feet high, good protection would probably be obtained up to 400 feet.

Frost Prevalence

Since they are dark in colour, muck and peat soils readily absorb heat rays, but because of low conductivity heat will not penetrate far into the soil. As a result they are slow in warming up to average seeding depth in the spring and very early seedings of most crops germinate poorly. For the same reason frost hazard during the spring and fall, and occasionally during the summer months, is greater than on mineral soils. During periods of low temperature the heat in the top few inches of soil may be lost rapidly by radiation and the accumulation of cold air at ground level be sufficient to cause frost. This effect is increased because areas of organic soil are usually low lying and partially or wholly surrounded by higher land. Accordingly, cold air, being denser and heavier, will flow onto such areas during calm, cool nights where it will remain and further lower the temperature. At the Ste. Clothilde Substation the temperature during summer nights without wind is usually three to five degrees lower on the muck area than on the surrounding higher mineral soil. During the past ten years light frosts have occurred five times in June and once in July. These have caused only slight damage to growing crops. Frosts in May and September have been more severe and on occasions have been responsible for serious loss.

Protection against frost can be effected in several ways. Usually when the soil is fairly compact at the surface, loss of accumulated heat, during the night, is slower than from freshly cultivated land. This is frequently sufficient to keep the temperature above freezing during cold nights. On several occasions it has been observed that where cultivation has stopped at the end of a day, preceding a cold night, potatoes have been injured by frost on the newly cultivated area but have escaped injury where the soil has not been disturbed.

Where the soil contains ample moisture some frost protection may be effected, since water increases the conductivity of the soil and more heat is stored during the day. Also, since water freezes at temperatures slightly higher than plants, heat is liberated in the freezing of the water, which affords further protection to the crop. Raising water in the ditches, when it is believed that frost will occur, will put more water into the soil, which will absorb and later radiate more heat. This may often be sufficient to save a tender crop. Where it is not desirable to wet the land, as in the case of a celery crop nearly ready for harvest, drenching the plants with a crop row sprayer, using water only, in the early evening may give protection up to three to four degrees. Even if the water on the leaves and stems freezes, the heat liberated in freezing may be enough to protect the crop.

Protection from frost may be effected by using heaters, and by burning small piles of brush or rubbish at intervals over the crop area. The heaters, or small fires, warm the surrounding air, which rises and thus causes a general movement of the air over a considerable area. This results in a rise of temperature by mixing the upper warmer air with the dense cold air at ground level. In addition crops within the limit of radiation of heat from the heaters or fires are protected.

It has also been observed that potatoes, celery, and cucumbers, recently sprayed with a fungicide, have escaped frost injury when unsprayed areas of the same crops were injured. This may be due in part, or entirely, to the hardening of the plants by the fungicide or the absorption of more heat during the day by the mineral matter in the spray material.

In general, frost damage is greater on areas where the soil is not in an advanced stage of decomposition. Such soils are not so highly activated as the more completely decomposed mucks and have a smaller population of microflora. Accordingly, less heat is generated and heat loss is more rapid by aeration because of the looser and more open texture. In addition, the unactivated soils usually contain less mineral matter, and, as a consequence, absorb less heat. It is also probable that the accumulation of mineral matter from fertilizer applications over several years has some effect in frost protection, in that the soil becomes capable of absorbing more heat. This is substantiated to some extent by the fact that muck lands that have been brought into a highly productive state, with liberal applications of a balanced fertilizer, are less susceptible to frost injury than adjacent land that has been left in the virgin state.

Crop Sequence

With organic soils, which are composed largely of organic matter, rotation of crops to build up organic matter is obviously unnecessary. Also, since the mineral content of these soils is very low it is necessary to apply a more complete balance of these nutrients, in fertilizer applications to each crop, than on mineral soils. Accordingly, a rotation of crops for the purpose of drawing on different mineral nutrients is not practical since the amounts available may be very small and the general balance easly disturbed. In general, vegetable crops may be grown year after year on the same site provided soil-borne diseases and insects affecting certain crops do not become prevalent and difficult to control. At the Ste. Clothilde Substation onions have been grown for ten years on the same site and crop yields have steadily increased. This is obviously because the continued applications of a balanced fertilizer containing the necessary trace elements has steadily increased the productivity of the soil. It is also common practice to grow potatoes on organic soil, where the pH value is favourable for the control of scab, for several years or until soil-borne disease becomes prevalent. Carrots are critical as to the height of the water-table, and in order to produce carrots of good quality and smooth shape, it is often desirable to continue growing the crop on a site where conditions are satisfactory.

Weed Control

Organic soils, when well managed, are highly productive for useful crops but the same conditions make them equally productive for weeds. If weed control is neglected with row crops such as carrots, onions, and celery, the growth and number of weeds becomes almost unbelievable. In weed control experiments at Ste. Clothilde, up to and over 1500 weeds per square yard have been counted in check plots of onions. Under such conditions useful plants cannot develop. Therefore, efficient and timely weed control practices are essential if crops are to be grown successfully.

The constant use of the cultivator and hoe will, of course, keep weeds under control in row crops, but, with many crops and heavy weed infestations, the cost of control by cultivation and hand weeding is prohibitive. At Ste. Clothilde this has amounted to over one hundred dollars per acre for carrots and onions. Furthermore, these heavy infestations seem to continue for years even when every effort is made to prevent weeds from producing seed. Apparently the seeds of many weeds remain virile for years in organic soils and germinate when moved up or down to a depth in the soil where conditions may be favourable. In this way new crops of weeds may make their appearance for several years even although perfect weed control may have been maintained each year.

It has also been noted that complete seasonal control of weeds by mechanical means is difficult on organic soils. If there is even a small amount of root left on the plants, when weeds are torn out by cultivation, or cut off with a hoe, they will take root and be growing again in a few days unless they are raked off. Also, under favourable conditions, such weeds as lamb's quarters and purslane will root as cuttings if pieces of the stem are left on the ground. The cultivator and hoe can be used to better advantage on crops that are grown in rows spaced from two to three feet apart, with the plants a foot or more apart in the row, than on the more closely planted crops. Weeds can be hoed from between the plants into the space between the rows and kept stirred with a cultivator until they are dead.

Efficient weed control in potato plantations can be effected by a method that is now in common use by producers on organic soils. This consists of hilling the land to a height of seven or eight inches over the newly planted sets and completely levelling the land with a drag when the potato sprouts have reached normal ground level. This moves many of the newly geminated weeds to the space between the rows where they can be destroyed by cultivation. Later, when more weeds begin to grow close to the potato plants, they can be buried, and thus suppressed, by a partial hilling. The process can be repeated until, with the final hilling at the time of potato bloom, weeds are well under control.

Chemical weed control is efficient and economical with many crops on organic soils. In general, pre-emergence treatments have not proved successful at Ste. Clothilde with early seeded crops. At this time in the season organic soils are cooler than mineral soils and weed seeds do not germinate early. Actually, in average seasons, onion seeds will germinate and the plants emerge several days before weeds make their appearance. Therefore, for this type of crop, selective weed killers are more useful. For later sown crops, when seasonal conditions are such that the land cannot be cleaned by cultivation before seeding time, pre-emergence treatments have proved very effective. Several of the dinitro compounds and a number of oils, such as Stoddard Solvent, have proved effective for this type of weed control when used as recommended by the manufacturers.

Weeds in carrots, celery, parsnips, and parsley can be almost completely eliminated with Stoddard Solvent without injury to the crop. This material is applied directly to the crop in a low pressure spray when the air temperature is 70°F. or lower. The amount to apply will vary with the amount and size of the weed growth, but, in general, 50 or 60 gallons per acre is sufficient. If well timed, one application will usually be all that is necessary. Onions can also be kept free from weeds by one or two sprays with potassium cyanate. This material must be used when the weeds are small and within a narrow range as to the amount per acre. The onion plant has a high degree of resistence to this chemical in solutions up to one per cent while not more than an inch or two in height, and can stand a two per cent solution when five or six inches high. Stronger solutions will injure the onions. If weeds are permitted to get beyond the seedling stage they are, of course, more difficult to kill. However, the treatment is quite efficient and like other selective herbicides will control weeds at a fraction of the cost of hand weeding.

SUMMARY OF FERTILIZER RECOMMENDATIONS FOR ORGANIC SOILS IN QUEBEC AND EASTERN ONTARIO

Crop	Rate per Acre	Fertilizer Formulae		
		Normal Muck	Alkaline Muck	Peat and Acid Muck
	lb.	pH 5—7	pH 7·1—8·5	pH below 5
Asparagus	400– 800	2– 8–16	2–8–20	Unsuitable
Beans	300– 600	0– 8–16	0–8–20	3–12–16
Beets (table)	500– 800	2– 8–16	2–8–20	3–12–16
Broccoli	500– 800	2– 8–16	2–8–20	3–12–16
Cabbage	600–1,000	2– 8–16	2–8–20	2– 8–16
Carrot (table)	500– 800	2– 8–16	2–8–20	5–10–13
Cauliflower	800–1,200	2– 8–16	2–8–20	5–10–13
Celery (early)	1,200–1,800	2– 8–16	2–8–16	Unsuitable
Celery (storage)	1,200–1,800	2– 8–16	2–8–20	Unsuitable
Cucumber	400– 800	0– 8–16	0–8–20	2– 8–16
Lettuce	600–1,000	2– 8–16	2–8–16	3–12–16
Muskmelon	400– 800	2– 8–16	2–8–20	3–12–16
Mint	200– 400	2– 8–16	2–8–20	2– 8–16
Onion	1,000–1,500	2–12–10	2–8–16	3–12–16
Parsnip	600–1,000	2– 8–16	2–8–20	3–12–16
Pea	400– 700	2–12–10	2–8–16	3–12–16
Pepper	800–1,500	2– 8–16	2–8–20	5–10–13
Potato	1,000–1,500	2– 8–16	Unsuitable	3–12–16
Pumpkin	300– 600	0– 8–16	0–8–20	2– 8–16
Radish	500–1,000	2– 8–16	2–8–16	5–10–13
Spinach	600–1,000	2– 8–16	2–8–20	3–12–16
Squash	300– 600	0– 8–16	0–8–20	2– 8–16
Sweet corn	400– 800	2– 8–16	0–8–16	Unsuitable
Tomato	500–1,000	2–12–10	0–12–16	3–12–16
Turnip (Swede)	600–1,000	2– 8–16	2–8–20	5–10–13

For newly broken organic soil the maximum rate, as indicated in the foregoing summary, should be applied for one year at least. In addition, extra potash may be required for celery for two or three years. As the soil becomes activated by additional fertilizer applications and cultivation, lower rates will usually be sufficient.

On shallow muck soils that have been in cultivation for a relatively long time, so that the organic layer has become reduced in depth to less than one foot, more nitrogen and less potash is required in the fertilizer application. For such conditions the recommendations for peat and acid muck should be followed.

Copper is essential for many crops on organic soils. Of these onions seem to demand the most, and in some instances applications of 100 to 150 pounds of copper sulphate have given positive results. On reclaimed land that has been wholly or partly under water applications up to 200 pounds have been found necessary for the first year. However, on normal muck or peat, yearly applications of 30 to 50 pounds of copper sulphate have been found sufficient for copper-hungry crops such as onions, spinach, and carrots. For other crops, where a copper deficiency exists, similar amounts applied every second or third year should prove sufficient. Where potatoes and celery are sprayed or dusted normally with materials such as bordeaux mixture and fixed copper, there is no need to apply copper to the soil as sufficient will be absorbed through the foliage to meet plant requirements. Also, the residue left in the soil, after several crops of celery or potatoes, will be sufficient for most crops for one or two years.

Where boron deficiency is known to exist, the application of 15 or 20 pounds of borax per acre is apparently sufficient for most crops. For celery, up to 40 pounds per acre may be required for one year, with annual applications of 20 pounds. When sprayed on the foliage, with bordeaux or fixed copper, one-half the amount required for a soil application will correct the deficiency for one year only. The customary rate is five pounds of borax to 100 gallons of spray included in two or three applications. For alkaline muck, where boron is deficient, the rate for soil applications should be increased by 50 per cent.

Boron should not be applied unless the need for it has been indicated, since an excess in the soil is toxic to plants.

Manganese deficiency in normal muck or peat can usually be corrected for such crops as spinach, cabbage, cauliflower, broccoli, and beans by a soil application of 40 or 50 pounds per acre of manganese sulphate every second or third year. For celery, annual applications may be necessary. On alkaline mucks at least double this amount may be required. In general, applications of manganese sulphate applied as a spray on the foliage are more effective than soil applications. From one-third to one-half the amount required for a soil application will correct the deficiency for one year. It can be applied alone in water or combined with copper sprays at 10 to 12 pounds per 100 gallons of liquid.

LIBRARY/BIBLIOTHEQUE
AGRICULTURE CANADA OTTAWA K1A 0C5
3 9073 00079541 1

EXPERIMENTAL FARMS SERVICE

Acting Director, E. S. Hopkins, B.S.A., M.Sc., Ph.D.

Dominion Field Husbandman	P. O. Ripley, B.S.A., M.Sc., Ph.D.
Dominion Horticulturist	M. B. Davis, B.S.A., M.Sc.
Dominion Cerealist	C. H. Goulden, B.S.A., M.S.A., Ph.D.
Dominion Animal Husbandman	Vacant.
Dominion Agrostologist	T. M. Stevenson, B.S.A., M.Sc., Ph.D.
Dominion Poultry Husbandman	H. S. Gutteridge, B.S.A., M.Sc.,
Chief, Tobacco Divison	N. A. MacRae, B.A., M.Sc., Ph.D.
Dominion Apiculturist	C. A. Jamieson, B.S.A.
Chief Supervisor of Illustration Stations	J. C. Moynan, B.S.A.
Economic Fibre Specialist	R. J. Hutchinson.

NEWFOUNDLAND

Officer-in-Charge, Experimental Substation, St. Johns, I. J. Green, B.S.A.

PRINCE EDWARD ISLAND

Superintendent, Experimental Station, Charlottetown, R. C. Parent, B.S.A., M.Sc.
Superintendent, Experimental Fur Ranch, Summerside, C. K. Gunn, B.Sc., M.Sc., Ph.D.

NOVA SCOTIA

Superintendent, Experimental Farm, Nappan, W. W. Baird, B.S.A.
Superintendent, Experimental Station, Kentville, A. Kelsall, B.S.A.

NEW BRUNSWICK

Superintendent, Experimental Station, Fredericton, S. A. Hilton, B.S.A., M.S.A.

QUEBEC

Superintendent, Experimental Station, Lennoxville, J. A. Ste. Marie, B.S.A.
Superintendent, Experimental Station, Ste. Anne de la Pocatiere, J. R. Pelletier, B.S.A., M.A., M.Sc.
Superintendent, Experimental Station, L'Assomption, R. Bordeleau, B.S.A.
Superintendent, Experimental Station, Normandin, A. Belzile, B.S.A.
Officer-in-Charge, Experimental Substation, Ste. Clothilde, F. S. Browne, B.S.A.

ONTARIO

Central Experimental Farm, Ottawa.
Superintendent, Experimental Station, Kapuskasing, F. X. Gosselin, B.S.A.
Superintendent, Experimental Station, Harrow, H. F. Murwin, B.S.A.
Officer-in-Charge, Experimental Substation, Delhi, L. S. Vickery, B.S.A., M.Sc.
Officer-in-Charge, Experimental Substation, Smithfield, D. S. Blair, B.S.A., M.Sc.
Officer-in-Charge, Experimental Substation, Woodslee, J. W. Aylesworth, B.S.A., M.S.

MANITOBA

Superintendent, Experimental Farm, Brandon, R. M. Hopper, B.S.A., M.Sc.
Superintendent, Experimental Station, Morden, W. R. Leslie, B.S.A.
Officer-in-Charge, Pilot Flax Mill, Portage la Prairie, E. M. MacKey, B.S.A.

SASKATCHEWAN

Superintendent, Experimental Farm, Indian Head, J. G. Davidson, B.A., B.S.A., M.S.A.
Superintendent, Experimental Station, Scott, G. D. Matthews, B.S.A.
Superintendent, Experimental Station, Swift Current, G. N. Denike, B.S.A.
Superintendent, Experimental Station, Melfort, H. E. Wilson, B.S.A.
Superintendent, Experimental Substation, Regina, J. R. Foster, B.S.A.
Superintendent, Forest Nursery Station, Indian Head, John Walker, B.Sc., M.S.
Superintendent, Forest Nursery Station, Sutherland, W. L. Kerr, B.S.A., M.Sc.

ALBERTA

Superintendent, Experimental Station, Lacombe, G. E. DeLong, B.S.A., M.Sc.
Superintendent, Experimental Station, Lethbridge, A. E. Palmer, B.Sc., M.Sc.
Superintendent, Experimental Station, Beaverlodge, E. C. Stacey, B.A., M.Sc.
Officer-in-Charge, Range Experiment Station, Manyberries, H. F. Peters, B.S.A.
Officer-in-Charge, Experimental Substation, Fort Vermilion, V. J. Lowe.

BRITISH COLUMBIA

Superintendent, Experimental Farm, Agassiz, W. H. Hicks, B.S.A.
Superintendent, Experimental Station, Summerland, R. C. Palmer, B.S.A., M.Sc., D.Sc.
Superintendent, Experimental Station, Prince George, F. V. Hutton, B.S.A.
Superintendent, Experimental Station, Saanichton, J. J. Woods, B.S.A., M.S.A.
Superintendent, Experimental Substation, Smithers, W. T. Burns, B.S.A., M.Sc.
Officer-in-Charge, Range Experiment Station, Kamloops, T. G. Willis, B.S.A., M.S.A.

YUKON AND NORTHWEST TERRITORIES

Officer-in-Charge, Experimental Substation, Whitehorse, Y.T., J. W. Abbott.
Officer-in-Charge, Experimental Substation, Fort Simpson, N.W.T., J. A. Gilbey, B.S.A., M.Sc.

OTTAWA
EDMOND CLOUTIER, C.M.G., O.A., D.S.P.
KING'S PRINTER AND CONTROLLER OF STATIONERY
1951